Contribution ID: **20** Type: 海报展示

Spectrum estimation from transmission measurements of Inverse Compton Scattering gamma rays based on a modified Expectation Maximization method

摘要

逆康普顿散射（ICS）光源的能谱测量既是评估系统运行状态的关键指标，也是后续应用研究的基础。基于最大期望值（EM）算法的衰减法能谱重建方法已广泛应用于 X 射线或韧致辐射能谱测量。然而，针对 ICS 源的准单能 γ 射线能谱，由于材料衰减系数变化率较低，传统 EM 算法收敛速度过慢而难以实现有效重建。本研究提出改进的 EM 算法，显著提升了收敛速度。通过蒙特卡洛模拟获得 ICS 源的 γ 能谱后，采用数值模拟验证了该方法在不同测量误差条件下对平均能量 530keV（能散 1.1%）和 2853keV（能散 1.28%）准单能 γ 射线的重建效果。结果表明，改进算法能以更少迭代次数获得优于传统方法的能谱估计，但要求透射测量精度分别达到 10^(-4) 和 10^(-5) 量级。

关键词

逆康普顿散射；能谱测量；最大期望值法

Abstract

The energy spectrum estimation of an inverse Compton scattering (ICS) source is not only a key indicator for assessing whether the system is operating normally, but also serves as the foundation for further application studies. Spectrum estimation from transmission measurements using the expectation maximization (EM) method has been widely applied for X-ray spectra or Bremsstrahlung spectra. However, for quasi-monochromatic gamma ray spectra of ICS sources, the low rate of change in the attenuation coefficients of materials causes the traditional EM method to converge too slowly, making it ineffective for spectrum reconstruction. We proposed a modified EM method that significantly accelerated the convergence rate. The energy spectra of an ICS gamma ray source were obtained using Monte Carlo simulations. Numerical simulations were carried out to test the feasibility of estimating quasi-monochromatic spectra with mean energies of 530 keV (energy spread of 1.1%), and 2853 keV (energy spread of 1.28%) under various measurement error conditions. The results demonstrated that the modified EM method can provide better approximations of quasi-monochromatic gamma ray spectra with fewer iterations than the traditional EM method, but the transmission measurement accuracy were required to reach 10^(-4), and 10^(-5) respectively.

Keywords

Inverse Compton Scattering；spectrum estimation；Expectation Maximization method

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Session Classification: 海报展示

Track Classification: 02 海报展示: 海报展示